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International application number: PCT/US05/003988

International filing date: 04 February 2005 (04.02.2005)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 60/541,660
Filing date: 04 February 2004 (04.02.2004)

Date of receipt at the International Bureau: 02 September 2005 (02.09.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

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APPLICATION NUMBER: ***60/541,660***
FILING DATE: ***February 04, 2004***
RELATED PCT APPLICATION NUMBER: ***PCT/US05/03988***

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17607 U.S. PTO
020404

PTO/SB/16 (08-03)
Approved for use through 07/31/2006. OMB 0651-0032
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. **EV 417440719 US**

031431 U.S. PTO
60/541660
020404

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Additional inventors are being named on the ____________ *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

THE USE OF TWO OR MORE SENSORS IN A NUCLEAR QUADRUPOLE RESONANCE DETECTION SYSTEM TO IMPROVE SIGNAL-TO-NOISE RATIO

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ Specification *Number of Pages* 16 ☐ CD(s), Number ________

☑ Drawing(s) *Number of Sheets* 2 ☐ Other (specify) ________

☐ Application Date Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☐ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees.

☑ The Director is herby authorized to charge filing fees or credit any overpayment to Deposit Account Number: **04-1928**

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FILING FEE Amount ($): $160.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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[Page 1 of 2]

Respectfully submitted,

SIGNATURE ________

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Date February 4, 2004

REGISTRATION NO. 32,255
(if appropriate)
Docket Number: CL2466USPRV

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

17607 U.S. PTO 020404

PTO/SB/17 (10-03)
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FEE TRANSMITTAL for FY 2004

Effective 10/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 160.00

Complete if Known	
Application Number	TO BE ASSIGNED
Filing Date	February 3, 2004
First Named Inventor	Daniel B. Laubacher
Examiner Name	
Art Unit	
Attorney Docket No.	CL2466 US PRV

METHOD OF PAYMENT (check all that apply)

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☑ Deposit Account:

Deposit Account Number: 04-1928

Deposit Account Name: E. I. du Pont de Nemours and Company

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Fee ($)	Small Entity Fee Code	Fee ($)	Fee Description	Fee Paid
1001	770	2001	385	Utility filing fee	
1002	340	2002	170	Design filing fee	
1003	530	2003	265	Plant filing fee	
1004	770	2004	385	Reissue filing fee	160.00
1005	160	2005	80	Provisional filing fee	

SUBTOTAL (1) ($) 160.00

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		X	18	=	
Independent Claims		- 3** =		X	86	=	
Multiple Dependent ☐ YES					290.00	=	

Large Entity Fee Code	Fee ($)	Small Entity Fee Code	Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0.00

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Fee ($)	Small Entity Fee Code	Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	420	2252	210	Extension for reply within second month	
1253	950	2253	475	Extension for reply within third month	
1254	1,480	2254	740	Extension for reply within fourth month	
1255	2,010	2255	1,005	Extension for reply within fifth month	
1401	330	2401	165	Notice of Appeal	
1402	330	2402	165	Filing a brief in support of an appeal	
1403	290	2403	145	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,330	2453	665	Petition to revive - unintentional	
1501	1,330	2501	665	Utility issue fee (or reissue)	
1502	480	2502	240	Design issue fee	
1503	640	2503	320	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	770	2809	385	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	770	2810	385	For each additional invention to be examined (37 CFR 1.129(b))	
1801	770	2801	385	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) ____________

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 0.00

SUBMITTED BY				(Complete *(if applicable)*)	
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PROVISIONAL APPLICATION COVER SHEET
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Docket Number CL2466USPRV

INVENTOR(S)/APPLICANT(S)		
Given Name (first and middle [if any]	Family or Surname	Residence (City and either State or Foreign Country)
CHARLES	WILKER	WILMINGTON, DELAWARE

Number 2 of 2

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TITLE
THE USE OF TWO OR MORE SENSORS IN A NUCLEAR QUADRUPOLE RESONANCE DETECTION SYSTEM TO IMPROVE SIGNAL-TO-NOISE RATIO

FIELD OF THE INVENTION

This invention relates to a nuclear quadrupole resonance detection system and the use of two or more sensors tuned to the same nuclear quadrupole resonance frequency and simultaneously detecting the nuclear quadrupole resonance signal, thereby providing improved nuclear quadrupole resonance detection system performance.

BACKGROUND OF THE INVENTION

The use of nuclear quadrupole resonance (NQR) as a means of detecting explosives and other contraband has been recognized for some time, see e.g., T. Hirshfield et al., J. Molec. Struct. 58, 63 (1980), A. N. Garroway et al., Proc. SPIE 2092, 318 (1993), and A. N. Garroway et al., IEEE Trans. On Geoscience and Remote Sensing 39, 1108 (2001). NQR provides some distinct advantages over other detection methods. NQR requires no external magnet such as required by nuclear magnetic resonance. NQR is sensitive to the compounds of interest, i.e., there is a specificity of the NQR frequencies.
One technique for measuring NQR in a sample is to place the sample within a solenoid coil that surrounds the sample. The coil provides a radio frequency (RF) magnetic field that excites the quadrupole nuclei in the sample and results in their producing their characteristic resonance signals. This is the typical apparatus configuration that might be used for scanning mail, baggage or luggage. There is also need for a NQR detector that permits detection of NQR signals from a source outside the detector, e.g., a wand detector, that could be passed over persons or containers as is done with existing metal detectors. Problems associated with such detectors using conventional

systems are the decrease in detectability with distance from the detector coil and the associated equipment needed to operate the system.

A detection system can have one or more coils that both transmit and receive or it can have separate coils that only transmit and only receive. A transmit or transmit and receive coil of an NQR detection system provides a magnetic field that excites the quadrupole nuclei in the sample and results in their producing their characteristic resonance signals that the coil receives. The NQR signals have low intensity and short duration. The transmit, receive, or transmit and receive coil preferably has a high quality factor (Q). The transmit, receive, or transmit and receive coil has typically been a copper coil and therefore has a Q of about 10^2. It can be advantageous to use a transmit, receive, or transmit and receive coil made of a high temperature superconductor (HTS) rather than copper since the HTS self-resonant coil has a Q of the order of 10^3-10^6. The large Q of the HTS self-resonant coil produces large magnetic field strengths during the RF transmit pulse and does so at lower RF power levels. This dramatically reduces the amount of transmitted power required to produce NQR signals for detection and thereby reduces the size of the RF power supply sufficiently so that it can be run on portable batteries. The large Q of the HTS self-resonant coil also plays an important role during the receive time. In view of the low intensity NQR signal, it is important to have a signal-to-noise ratio (S/N) as large as possible. The signal-to-noise ratio is proportional to the square root of Q so that the use of the HTS self-resonant coil results in an increase in S/N by a factor of 10-100 over that of the copper system. These advantages during both the transmit and the receive times enable a detector configuration that is small and portable. In particular, the use of a high temperature superconductor sensor, i.e., receive

coil, provides a distinct advantage over the use of an ordinary conductor coil.

An object of the present invention is to provide a NQR detection system with improved performance.

SUMMARY OF THE INVENTION

This invention provides a method for improving the performance of a nuclear quadrupole resonance detection system comprising:

a) using two or more sensors tuned to a specified nuclear quadrupole resonance frequency, wherein the two or more sensors simultaneously receive the specified nuclear quadrupole resonance signal; and

b) adding coherently the signals detected by the two or more sensors to thereby improve the signal-to-noise ratio.

The invention also provides a nuclear quadrupole resonance detection system comprising:

a) two or more sensors tuned to a specified nuclear quadrupole resonance frequency, wherein the two or more sensors simultaneously receive the specified nuclear quadrupole resonance signal; and

b) means to add coherently the signals detected by the two or more sensors to thereby improve the signal-to-noise ratio.

Preferably, the two or more sensors are used solely for sensing, i.e., receiving, the NQR signal, and a separate coil is used as the transmit coil. Preferably, the two or more sensors are high temperature superconductor coils. More preferably, the two or more sensors are high temperature superconductor planar coils. Most preferably, the HTS sensors are each comprised of two or more coupled high temperature superconductor self-resonant planar coils.

This invention for improving the signal-to-noise ratio and thereby the performance of a nuclear quadrupole resonance detection system is especially

important when the nuclear quadrupole resonance detection system is used for detecting the nuclear quadrupole resonance of explosives, drugs and other contraband.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 shows the HTS coil design of an HTS coil used in the Example.

Figure 2 is a schematic diagram of the experimental set-up used in the Example.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The instant invention provides a method for increasing the signal-to-noise ratio of a NQR detection system for scanning a potential source of NQR and a NQR detection system that provides this increased performance. To accomplish this, two or more sensors are tuned to a specified nuclear quadrupole resonance frequency and the signals detected by the two or more sensors are added coherently. As used herein, "tuned to a specified nuclear quadrupole resonance frequency" means that the two or more sensors are tuned to a frequency within a given nuclear quadrupole resonance emission line so that even if the two or more sensors are not tuned to exactly the same frequency, they are still detecting the same emission line.

The two or more sensors to detect the nuclear quadrupole resonance can be used only as receive coils or as transmit and receive coils. Preferably, separate coils are used to transmit the RF signal and to detect any NQR signal and the sensors are used solely as receive coils.

The transmit coils used in this invention can be made of copper, silver, aluminum or a high temperature superconductor. A copper, silver or aluminum coil is preferably in the form of a shielded-loop resonator (SLR) coil. SLR's have been developed to eliminate the detuning effect of the electrical interaction between the coil and the surrounding material.

Preferably, a copper SLR transmit coil is used to apply the RF signal to the sample.

Preferably, the two or more sensors are high temperature superconductor (HTS) coils. A high temperature superconductor coil is preferably in the form of a self-resonant planar coil, i.e., a surface coil, with a coil configuration of HTS on one or, preferably, both sides of a substrate. High temperature superconductors are those that superconduct above 77K. The high temperature superconductors used to form the HTS self-resonant coil are preferably selected from the group consisting of $YBa_2Cu_3O_7$, $Tl_2Ba_2CaCu_2O_8$, $TlBa_2Ca_2Cu_3O_9$, $(TlPb)Sr_2CaCu_2O_7$ and $(TlPb)Sr_2Ca_2Cu_3O_9$. Most preferably, the high temperature superconductor is $Tl_2Ba_2CaCu_2O_8$. It is often advantageous to be able to fine tune the resonance frequency of the sensor. One means for accomplishing such tuning is to use two or more coupled high temperature superconductor self-resonant coils. The resonance frequency of the fundamental symmetric mode of the two or more coupled high temperature superconductor self-resonant coils can be varied by mechanically displacing the coils with respect to one another and these coupled coils serve as the HTS sensor. Preferably, the two or more coils are planar, i.e., surface, coils. Each planar coil can have an HTS coil configuration on only one side of the substrate, but preferably, has essentially identical HTS coil configurations on both sides of the substrate. Most preferably, each HTS sensor is comprised of two or more coupled high temperature superconductor self-resonant planar coils.

A HTS self-resonant coil can be formed by various known techniques. A preferred technique is described in the Example.

As indicated above, when two or more coupled high temperature superconductor self-resonant coils are used as a sensor, the resonance frequency of the fundamental symmetric mode of the two or more coupled high

temperature self-resonant coils can be varied by mechanically displacing the coils with respect to one another and this is one means to tune the resonance frequency of the sensor to a specified nuclear quadrupole resonance frequency. Alternatively, a circuit can be used to provide the tuning of the resonance frequency of the sensor to a specified nuclear quadrupole resonance frequency. The circuit can be comprised of a single loop or coil to inductively couple the circuit to the high temperature superconductor self-resonant sensor, a reactance in series with the single loop or coil and means to enable the reactance to be connected to and disconnected from the single loop or coil. The single loop or coil can be made of a regular conductor such as copper or a high temperature superconductor. The reactance can be an inductance, capacitance or combination of both. Preferably, the means to enable the reactance to be connected to and disconnected from the single loop or coil is comprised of at least one mechanical switch or diode. Preferably, the reactance can be varied so that the resonance frequency can be adjusted to more than one frequency. One way of accomplishing a variable reactance is to have the reactance comprised of two or more capacitors in parallel, each of which can be individually connected to or disconnected from the single loop or coil. Alternatively, a variable reactance can be comprised of two or more inductors in series, each of which can be individually connected to or disconnected from the single loop or coil by a switch or diode that can short-circuit the inductor and thereby essentially remove it from the circuit.

The NQR signals detected by the two or more sensors can be added coherently, i.e., the phases of the individual signals are adjusted to add constructively, by various analog and digital techniques. In the analog technique for coherent addition, the electrical path from each sensor to the

combination point, at which the signals are added, is adjusted so that the signals add constructively at the combination point. When the two or more sensors are essentially equidistant from the sample that is the source of the nuclear quadrupole resonance signal, the electrical paths from the sensors to the combination point can be made essentially identical thereby insuring that the signals add constructively at the combination point. In the digital technique for coherent addition, before combination each signal detected by the two or more sensors is multiplied by a constant complex factor that can be measured or calculated to correct for phase differences between the signal paths and thereby insure that the signals add constructively at the combination point. The constant complex factor is specific to each electrical path from each sensor to the combination point. Typically, the signals will be amplified before they are added.

The advantages in using an array of two or more sensors over using of a single sensor can be seen as follows. The signal S obtained by using an array of n sensors and coherently adding the signals is proportional to n. Assuming that the noise present is random, the noise N, after the coherent addition, is proportional to $1/n^{0.5}$. Therefore S/N is proportional to $n^{1.5}$. An array of two sensors therefore increases S/N by a factor of nearly 3. An array of four sensors increases S/N by a factor of 8.

The use of HTS self-resonant coils as sensors makes the instant invention especially attractive. The HTS self-resonant coils have high Q's and relatively small size and make the use of an array of two or more sensors more feasible.

Provision must be made for a power supply to supply power for transmitting the RF pulse. If one or more HTS coils are used, provision must also be made for cooling the HTS to liquid nitrogen temperature.

EXAMPLE OF THE INVENTION

The purpose of this Example is to demonstrate the increase in S/N when two sensors are used to simultaneously detect a frequency and the signals from the sensors are added coherently.

Each HTS self-resonant sensor is comprised of two coupled essentially identical $Tl_2Ba_2CaCu_2O_8$ planar coils. Each of the coupled coils is on a lanthanum aluminate ($LaAlO_3$) substrate with the coil design configuration shown in Figure 1 on both sides of the substrate.

A clean, polished single crystal $LaAlO_3$ substrate with a diameter of 2 inches (5.1 cm) and an approximate thickness of 0.02 inches (0.5 mm) was obtained from Litton Airtron, Morris Plains, NJ. Off-axis magnetron sputtering of a Ba:Ca:Cu oxide target was used to deposit, at room temperature (about 20°C), an amorphous precursor Ba:Ca:Cu oxide film on both sides of the substrate. This amorphous Ba:Ca:Cu oxide film was about 550 nm thick and had a stoichiometry of about 2:1:2. The precursor film was then thallinated by annealing it in air for about 45 minutes at 850°C in the presence of a powder mixture of $Tl_2Ba_2Ca_2Cu_3O_{10}$ and Tl_2O_3. When this powder mixture is heated, Tl_2O evolves from the powder mixture, diffuses to the precursor film and reacts with it to form the $Tl_2Ba_2CaCu_2O_8$ phase.

The sample was then coated with photoresist on both sides and baked. A coil design mask with the design shown in Figure 1 was prepared. The coil has an inner radius of about 10.5 mm and an outer radius of about 22.5 mm. The outermost HTS ring 31 of the coil is about 2 mm wide and the innermost HTS ring 32 is about 3.5 mm wide. The intermediate HTS rings 33 are about 250 μm wide with about 250 μm gaps between the rings. The coil design mask was then centered on the photoresist covering the $Tl_2Ba_2CaCu_2O_8$ film on the front side of the substrate and exposed to ultraviolet light. The coil design mask was then centered on the

photoresist covering the $Tl_2Ba_2CaCu_2O_8$ film on the back side of the substrate and exposed to ultraviolet light. The resist was then developed on both sides of the substrate and the portion of the $Tl_2Ba_2CaCu_2O_8$ film exposed when the resist was developed was etched away by argon beam etching. The remaining photoresist layer was then removed by an oxygen plasma. The result was a coil structure comprised of the single crystal $LaAlO_3$ substrate with a high temperature superconductor $Tl_2Ba_2CaCu_2O_8$ pattern of the configuration shown in Figure 1 centered on each side of the single crystal $LaAlO_3$ substrate. The process was repeated three times in essentially the same way to produce three coils essentially identical to the first.

A schematic diagram of the experimental set-up used to demonstrate the increase in S/N when two sensors are used and the signals from the sensors are added coherently is shown in Figure 2. Two of the essentially identical coils were used as one sensor 11. Sensor 11 demonstrates the use of a sensor comprised of two coupled high temperature superconductor self-resonant planar coils. The other two essentially identical coils were used as the second sensor 12. The sensors 11 and 12 were each immersed in liquid nitrogen held in Nalgene® (Nalge Nunc International, Rochester, NY) dewars 13 and 14, respectively, and each was tuned to 3.6 MHz. An Agilent E4433B Signal Generator (Agilent Technologies, Palo Alto, CA) 15 and a transmit loop 16 were used in place of a NQR source. The transmit loop 16 was comprised of a loop of copper wire approximately 2 cm in diameter. The transmit loop 16 was placed so that the sensors 11 and 12 were approximately equidistant from it, i.e., about 0.5 m away from each of the sensors, with the plane of the transmit loop parallel to the planes of the coils of the sensors. The transmit loop was formed by removing the outer jacket and dielectric spacer from a piece of 0.080 inch (2 mm) coax cable 17. The transmit loop was

formed by bending the inner conductor into a circle and soldering it to the outer jacket of the coax cable just outside the point where the jacket and dielectric were removed. The signal generator provided a -10dBm signal at a frequency of 3.6 MHz. Two pick-up coils 18 and 19, each comprised of a loop of copper wire, were placed about 1 inch (2.5 cm) away from the sensors 11 and 12, respectively, with the plane of the pick-up coils parallel to the planes of the coils of the sensors. Each of the pick-up coils 18 and 19 was formed by removing the outer jacket and dielectric spacer from a piece of 0.080 inch (2 mm) coax cable 20 and 21, respectively. The loop was formed by bending the inner conductor into a circle and soldering it to the outer jacket of the coax cable just outside the point where the jacket and dielectric were removed. The coax cables 20 and 21 were each connected to a 93 ohm 2 m piece of RG62 cable 22 and 23, respectively, which were connected to a 50 ohm tee 24. This insured that the electrical phase along the two paths was essentially the same. The output of the tee 24 was fed to a Spectrum Analyzer R&S FSP 25 (Rohde & Schwarz GmbbH & Co., KG, Munchen, Germany).

The signal with only one sensor present was compared to that obtained using the two sensors. The use of the two sensors resulted in a 6 dB increase in signal. This demonstrates the increase in S/N when two sensors are used to simultaneously detect a frequency and the signals from the sensors are added coherently.

CLAIMS

What is claimed is:

1. A method for improving the performance of a nuclear quadrupole resonance detection system, the improvement comprising:

   a) using two or more sensors tuned to a specified nuclear quadrupole resonance frequency, wherein said two or more sensors simultaneously receive the specified nuclear quadrupole resonance signal; and

   b) adding coherently the signals detected by said two or more sensors to thereby improve the signal-to-noise ratio.

2. The method of claim 1, wherein said two or more sensors are used solely to detect said specified nuclear quadrupole resonance signal.

3. The method of claim 1, wherein said two or more sensors are high temperature superconductor self-resonant planar coils.

4. The method of claim 1, wherein said two or more sensors are each comprised of two or more coupled high temperature superconductor self-resonant planar coils.

5. The method of claim 3 or 4, wherein said two or more sensors are used solely to detect said specified nuclear quadrupole resonance signal.

6. The method of claim 3 or 4, wherein the high temperature superconductor is selected from the group consisting of $YBa_2Cu_3O_7$, $Tl_2Ba_2CaCu_2O_8$, $TlBa_2Ca_2Cu_3O_9$, $(TlPb)Sr_2CaCu_2O_7$ and $(TlPb)Sr_2Ca_2Cu_3O_9$.

7. The method of claim 6, wherein said high temperature superconductor is $Tl_2Ba_2CaCu_2O_8$.

8. The method of any of claims 1-4, further comprising using a copper shielded-loop resonator coil to apply the RF signal to the sample to be scanned for

nuclear quadrupole resonance, thereby exciting the quadrupolar nuclei of said sample.

9. The method of any of claims 1-4, wherein the electrical path from each of said two or more sensors to the combination point is adjusted so that said signals add constructively at said combination point.

10. The method of any of claims 1-4, wherein said two or more sensors are essentially equidistant from the sample that is the source of said nuclear quadrupole resonance signal and the electrical paths from each of said two or more sensors to the combination point are essentially identical so that said signals add constructively at said combination point.

11. The method of any of claims 1-4, wherein before combination said signals are each multiplied by a constant complex factor specific to each electrical path from each of said two or more sensors to the combination point to correct for phase differences between the signal paths and thereby insure that said signals add constructively at said combination point.

12. A nuclear quadrupole resonance detection system, comprising:

a) two or more sensors tuned to a specified nuclear quadrupole resonance frequency, wherein said two or more sensors simultaneously receive the specified nuclear quadrupole resonance signal; and

b) means to add coherently the signals detected by said two or more sensors to thereby improve the signal-to-noise ratio.

13. The nuclear quadrupole resonance detection system of claim 12, wherein said two or more sensors are used solely to detect said nuclear quadrupole resonance signal.

14. The nuclear quadrupole resonance detection system of claim 12, wherein said two or more sensors

are high temperature superconductor self-resonant planar coils.

15. The nuclear quadrupole resonance detection system of claim 12, wherein said two or more sensors are each comprised of two or more coupled high temperature superconductor self-resonant planar coils.

16. The nuclear quadrupole resonance detection system of claim 14 or 15, wherein said two or more sensors are used solely to detect said nuclear quadrupole resonance signal.

17. The nuclear quadrupole resonance detection system of claim 14 or 15, wherein said high temperature superconductor is selected from the group consisting of $YBa_2Cu_3O_7$, $Tl_2Ba_2CaCu_2O_8$, $TlBa_2Ca_2Cu_3O_9$, $(TlPb)Sr_2CaCu_2O_7$ and $(TlPb)Sr_2Ca_2Cu_3O_9$.

18. The nuclear quadrupole resonance detection system of claim 17, wherein said high temperature superconductor is $Tl_2Ba_2CaCu_2O_8$.

19. The nuclear quadrupole resonance detection system of any of claims 12-15, further comprising a copper shielded-loop resonator coil to apply the RF signal to the sample to be scanned for nuclear quarupole resonance, thereby exciting the quadrupolar nuclei of said sample.

20. The nuclear quadrupole resonance detection system of any of claims 12-15, further comprising electrical paths from each of said two or more sensors to a combination point at which said signals are added, wherein the electrical path from each of said two or more sensors to said combination point is adjusted so that said signals add constructively at said combination point.

21. The nuclear quadrupole resonance detection system of any of claims 12-15, further comprising electrical paths from each of said two or more sensors to a combination point at which said signals are added, wherein said two or more sensors are essentially equidistant from the sample that is the source of said

nuclear quadrupole resonance signal and said electrical paths from each of said two or more sensors to said combination point are essentially identical so that said signals add constructively at said combination point.

22. The nuclear quadrupole resonance detection system of any of claims 12-15, further comprising electrical paths from each of said two or more sensors to a combination point at which said signals are added, wherein before combination said signals are each multiplied by a constant complex factor specific to each electrical path from each of said two or more sensors to the combination point to correct for phase differences between the signal paths and thereby insure that said signals add constructively at said combination point.

23. The nuclear quadrupole resonance detection system of any of claims 12-15, wherein said nuclear quadrupole resonance detection system is used to detect explosives, drugs or other contraband.

24. The nuclear quadrupole resonance detection system of claim 16, wherein said nuclear quadrupole resonance detection system is used to detect explosives, drugs or other contraband.

25. The nuclear quadrupole resonance detection system of claim 17, wherein said nuclear quadrupole resonance detection system is used to detect explosives, drugs or other contraband.

26. The nuclear quadrupole resonance detection system of claim 18, wherein said nuclear quadrupole resonance detection system is used to detect explosives, drugs or other contraband.

27. The nuclear quadrupole resonance detection system of claim 19, wherein said nuclear quadrupole resonance detection system is used to detect explosives, drugs or other contraband.

28. The nuclear quadrupole resonance detection system of claim 20, wherein said nuclear quadrupole

resonance detection system is used to detect explosives, drugs or other contraband.

29. The nuclear quadrupole resonance detection system of claim 21, wherein said nuclear quadrupole resonance detection system is used to detect explosives, drugs or other contraband.

30. The nuclear quadrupole resonance detection system of claim 22, wherein said nuclear quadrupole resonance detection system is used to detect explosives, drugs or other contraband.

TITLE

THE USE OF TWO OR MORE SENSORS IN A NUCLEAR QUADRUPOLE RESONANCE DETECTION SYSTEM TO IMPROVE SIGNAL-TO-NOISE RATIO

ABSTRACT OF THE INVENTION

The use of two or more sensors tuned to the same nuclear quadrupole resonance frequency and simultaneously detecting the nuclear quadrupole resonance signal results in improved signal-to-noise ratio and therefore improved nuclear quadrupole resonance detection system performance.

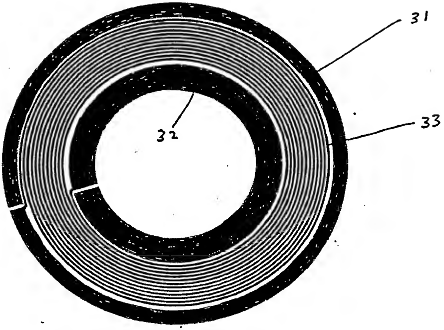
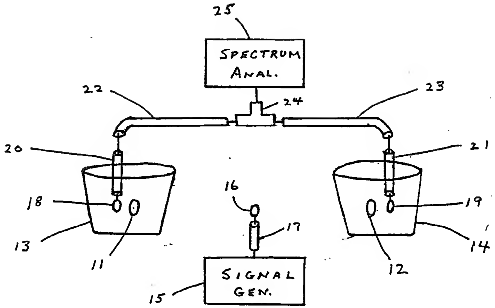


FIGURE 1



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SPECTRUM
ANAL.
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SIGNAL
GEN.
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FIGURE 2